THE GALLERY COLLECTING SYSTEM OF THE DES MOINES WATER COMPANY, DES MOINES, IOWA[1]

By A. T. Luce

The Des Moines Water Company is one of the pioneers, if not the first, to develop its water supply thoroughly by means of infiltration galleries. A number of cities have water supplies developed from underlying sand and gravel strata by means of wells but few, if any, have adopted the method used here. In order to understand the practical application of this method, it will be necessary first to fix clearly in mind the fundamental features of the water-bearing area, before undertaking to follow through the various stages of its development.

The water is obtained primarily from the Raccoon River. This stream lies in a southwesterly direction from Des Moines and discharges into the Des Moines River in the heart of the city. It has a drainage area of 3677 square miles above the city and a minimum flow of sufficient quantity to more than meet the needs of the city for years to come.

The most interesting feature of the river, from a water supply standpoint, is the geology of its valley in the vicinity of Des Moines. Here we find a broad valley, nearly 100 feet deep and a mile wide, which has been eroded in the clay, shale and rock of the natural topography and extending for many miles upstream with relatively steep sides, terminating in rolling plains above. It is evident that this valley was eroded by a preglacial stream which eventually cut its way to a hard bottom and later covered this bottom with clean sand and fine gravel brought down from the glaciers, and then, at a still later period, covered this gravel bed with from 5 to 10 feet of alluvium. As might be expected, this stratum of sand and gravel terminates at the foothills on either side but extends upstream for many miles. Borings have shown this to be true and many made by the Water Company affirm the fact that it is from 10 to 30 feet in thickness, very clean and uniform in size. An analysis of the bor-

[1] Read before the Iowa Section April 16, 1919.

ings shows no marked difference in the character of the material although in some places the sand predominates while in others the gravel. There is, however, little difference in the water-carrying capacity, the average effective size being about 0.42 mm., with a coefficient of uniformity of 4.00.

Owing to the fact that the surface of the valley lies below the level of the flood plane of the river, it is sparsely settled both within the city and for a long distance above it. Thus we find extending right in the city a large sand- and gravel-filled basin, sealed off from practically all outside contamination by the topography and the natural clay soil, through which meanders a river of ample size to furnish the water requirements for many years to come. During the greater portion of the year, this river is low in turbidity but it is subject to floods that periodically scour the silt deposits from its bed.

It was concluded early in the development of the Water Company that the sand of the river would act as a good filtering agent, and there was accordingly constructed in 1871 a steel tank 21 feet in diameter and 14 feet high, with perforated sides and closed top. This tank was sunk in the gravel on the south bank of the river until its top was 10 feet below low water and it was surrounded with coarse gravel. It has been estimated that this tank furnished water at the rate of 1,500,000 gallons per day for short periods. A direct river inlet was later connected for emergency use. In 1876 two more tanks were installed on the north bank of the river. These were similar to the original, being 12 feet in diameter and 12 feet high, with perforated sides and open bottom but having tops constructed of 12 by 12 inch timbers.

The first unit of the present collecting system was built in 1882. This was the suction well located in the station yard and approximately 800 feet from the river. It consists of a brick-lined well 50 feet in diameter and 35 feet deep, with walls 19 inches thick resting on an iron shoe. The well is roofed over below the ground and contains the suctions of the pumping engines. The top of the well is about 15 feet above the normal river level. Upon completion the well was capable of delivering 500,000 gallons per day. With this well and the three boxes a supply of from 2,000,000 to 3,000,000 gallons per day was obtained, although the draft upon the boxes was beginning to draw sand into the pumps and give more or less trouble.

In 1884 work was started on the first gallery. This gallery is known as the No. 1 gallery and extends, as shown in figure 1, from the suction well south under the tracks of the Rock Island railroad a distance of 260 feet, thence in a westerly direction along the railroad between it and the river for a distance of 817 feet, terminating at a point 150 feet from the river bank. It is 4 feet high by 5 feet wide and surrounded with 1 inch screened stone, as shown in figure 2. The bottom is open and the sides and top are made of 3 by 6-inch white elm timbers laid with $\frac{3}{8}$ inch spaces between. The gallery was built in open cut, the ditch varying from 17 to 27 feet in depth. It was completed in 1886.

The old iron tanks were abandoned in 1885 and the water drawn entirely from No. 1 gallery and the suction well. Thus we find that 34 years ago the entire water supply was developed by infiltration at a considerable distance from the river.

Owing to the steady growth of the city and the increasing demand for water the No. 2 or river gallery and river well were built in 1887. The well was located in the station yard and is 20 feet in diameter by 30 feet deep built with 20-inch brick walls resting on a wooden shoe. It is roofed over with brick arches supported by I-beams. In order to prevent wash from the gallery one-half of the bottom is floored with a baffle in the center. This gallery is 1994 feet in length and lies along the foot of the bluff on the north side of the railroad, terminating in an emergency inlet to the river. Like the No. 1 gallery, it is constructed of white elm timbers in open cut varying in depth from 15 to 30 feet. It is smaller, however, in size being only 4 feet wide by 4 feet 2 inches high with open bottom and tightly sheeted sides and top made of 4 by 6-inch white elm timbers set on a bed of screened broken limestone. At the time of completion of this gallery, there was ample infiltration to supply the domestic and fire demand of the city without recourse to the emergency river intake, the average daily consumption being about 2,000,000 gallons.

It was not necessary to augment this supply by additional galleries until 1894, when the consumption had increased to an average of nearly 3,000,000 gallons per day. During this year the No. 3 gallery was constructed. This gallery is an extension of the No. 1 gallery, beginning at the end of the old gallery and extending across the river and upstream parallel to it for a total distance of 1250 feet. It is 3 feet 8 inches high by 5 feet wide and was built with sides of 4 by 6-inch timbers in which $\frac{1}{4}$ inch spaces were left between timbers.

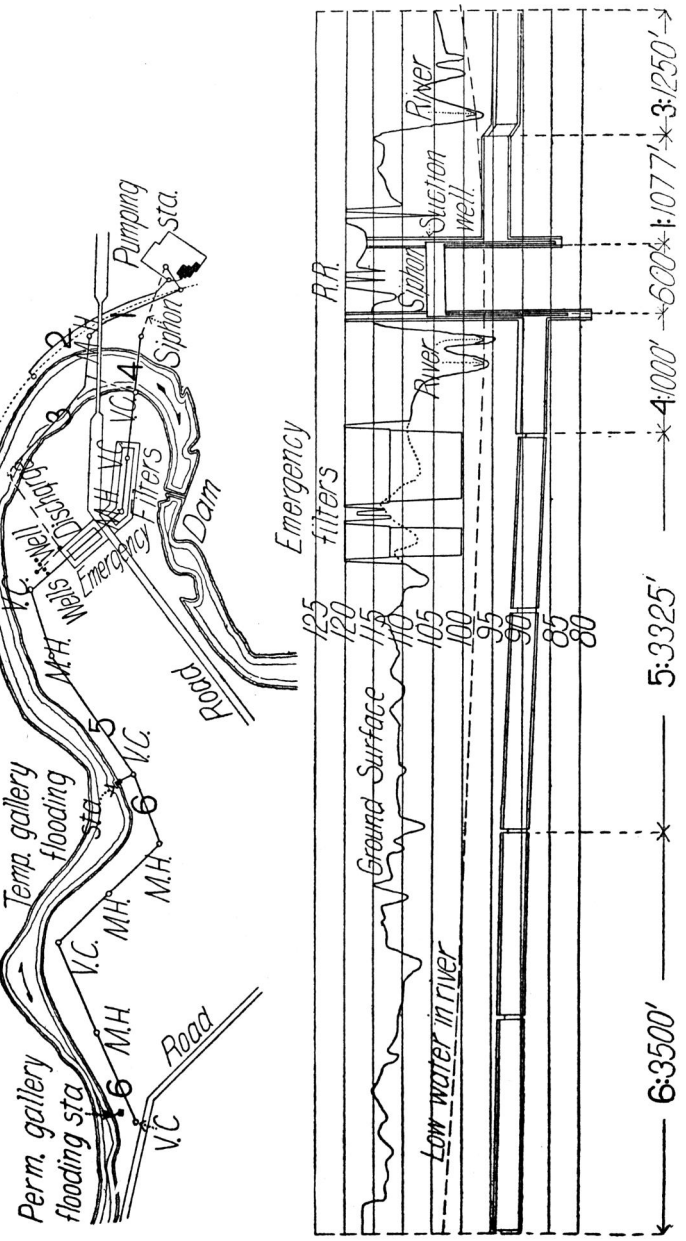

FIG. 1. THE GALLERY COLLECTING SYSTEM OF THE DES MOINES WATER COMPANY

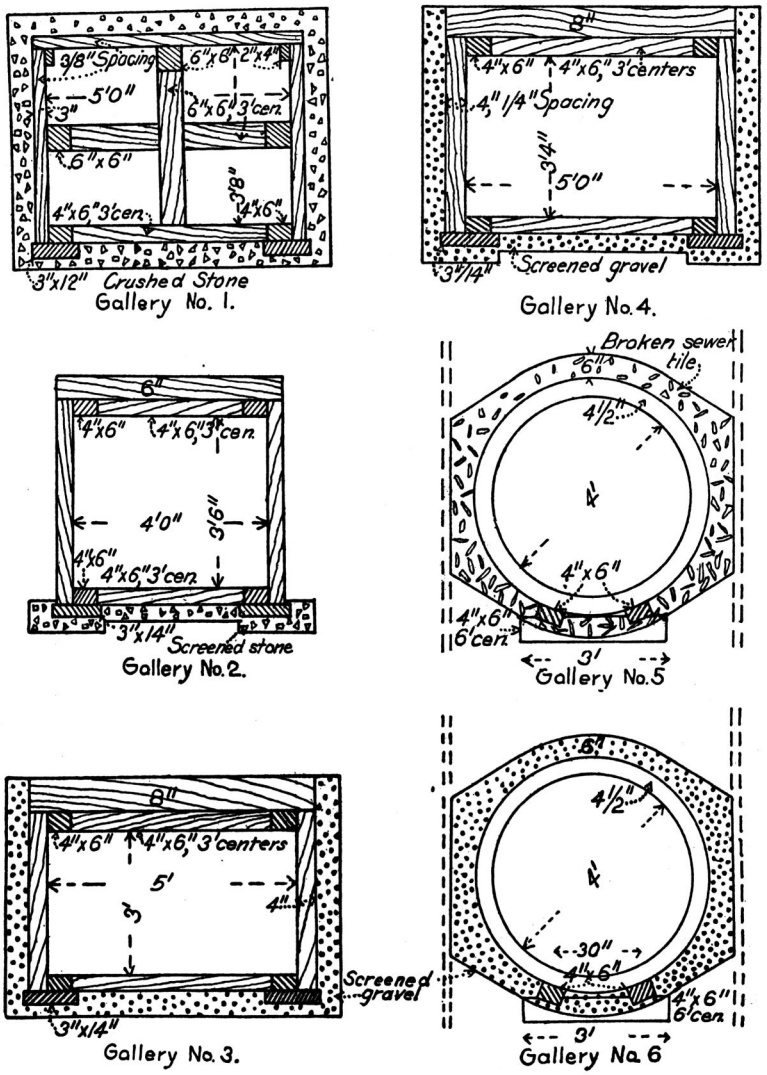

FIG. 2. CROSS-SECTIONS OF THE DES MOINES INFILTRATION GALLERIES

The top was made solid, 8 inches in thickness, and like the other two galleries, the bottom was left open. Screened gravel was placed on the sides and bottom of the gallery. For 150 feet, under the river, the gallery is protected by a 4-inch concrete slab. A low brush and rock-fill dam was thrown across the river below the galleries in the fall of this year which increased the head on the galleries about 2 feet.

Five 8-inch drive wells were constructed about 800 feet from the gallery in 1899. These wells were about 20 feet in depth, extending nearly to the clay subsoil, and were equipped with 8-foot strainers. Pumping was done by means of an electrically driven pump which discharged into the end of the No. 3 gallery, through a 16-inch cast iron pipe line. In 1900 it was decided that the operation of this equipment was detrimental to the flow in the galleries and the wells were accordingly abandoned.

It was not until 1904, that additional galleries were built. The No. 4 gallery was started in 1902 but floods and high water delayed the actual construction for two years. This gallery forms the first link in the present main gallery line and was built of similar construction to No. 3 gallery although it is 4 inches higher, being 4 feet by 5 feet in section. It was built in open cut at a depth varying from 10 to 30 feet, and extends from a point on the north bank of the river 600 feet from the suction well across the stream for a total distance of 1000 feet. The end of the gallery is connected to the suction well by means of a 36-inch cast iron siphon. A 20-inch cross connection was built between galleries Nos. 3 and 4, in order to equalize their flow. It is of interest to note that this gallery extends at right angles to the river and at its upper end is 400 feet from the nearest bank.

During times of low water it became necessary to irrigate and rake the sand bars along the river adjacent to the galleries in order to increase the yield. This procedure was expensive and more or less unsatisfactory and it was decided to extend the gallery system still further. After a careful investigation of the ground water contours and a further study of the water-bearing strata it was determined that over two-thirds of the water collected by the galleries came from the river and that the rate of this infiltration approximated 220,000 gallons per acre of river bed per day. It was accordingly concluded that extensions made parallel to the river would develop the greatest delivery.

Work was started on the No. 5 gallery in 1908. This gallery extends in a southwesterly direction from the end of gallery No. 4, a distance of 3325 feet, and consists of a series of concrete rings 4 feet in diameter, figure 3, laid on a timber cradle surrounded by 6 inches of crushed sewer tile. Each ring is 2 feet long and $4\frac{1}{2}$ inches thick, made of reinforced concrete, and has small lugs cast on one end $\frac{1}{4}$ inch high which serve as spacers between the adjacent rings. The excavation ranged from 20 to 27 feet in depth, and due to the intensely water-bearing character of the material solid sheeting had to be resorted to. Three pumping plants were used during the work, as it was necessary to handle water at rates varying from 4,000,000 to 12,000,000 gallons per day. Manholes were built at points where the direction of the gallery changed. This gallery is divided into two sections connected by 36 feet of 36-inch cast iron pipe and a gate valve. Cast iron pipe and valves were also placed at the beginning and end of the gallery. All three valves are located in valve chambers marked "V. C." in figure 1, made of brick with concrete bottoms. The work on this section of gallery was completed in 1910.

In order to dispense with the irrigation and raking of the sand bars during periods of low water, an emergency filter was built simultaneous with the construction of the No. 5 gallery. This filter consists of an earthern reservoir immediately above the gallery, divided into two sections by a street crossing. The filters are 30 feet wide at the bottom with side slopes of 1:1 and a total length of 850 feet, and are connected by a 24-inch vitrified tile. Water was originally admitted to them by gravity from the river through a 20-inch cast iron pipe. The bottom is at elevation 100 and the tops of the banks are at elevation 120. Without the emergency filter this gallery produced about 2,000,000 gallons per day and it was thought that there would be no further extensions needed for some time as the average daily consumption of the city was about 5,500,000 gallons per day. The demand for water, however, became greater than was anticipated, as the consumption increased over 50 per cent between 1907 and 1913, at which time it became apparent that the galleries would have to be again extended and accordingly work was started on No. 6 gallery in the fall of 1914.

The No. 6 gallery begins at the end of No. 5 gallery and parallels the river for a distance of 3500 feet. It is identical in construction with the latter gallery and is likewise divided into two sections by a short stretch of 36-inch cast iron pipe and a valve. The excavation

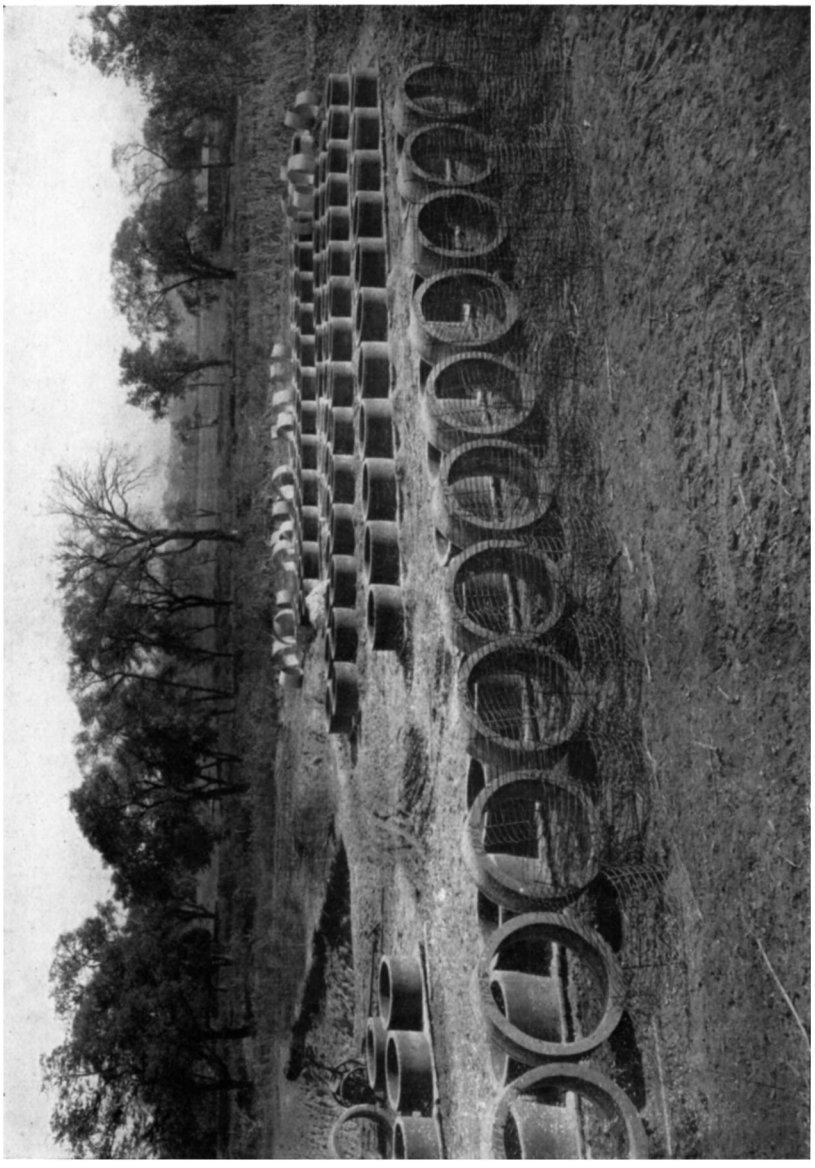

FIG. 3. YARD WHERE 4-FOOT REINFORCED CONCRETE RINGS WERE MADE

ranged from 18 to 20 feet in depth and was done by two locomotive cranes operating on standard gauge track on either side of the excavation. Steel sheet piling was used for lining the trenches and was driven by steam hammers supported by the cranes, or by special towers, figure 4. Water was pumped from the ditch at rates varying from 2,000,000 to 8,000,000 gallons per day. This gallery was completed and put into operation early in 1917 and completed the extensions up to the present time.

Owing to the lowering of the river level about 2 feet by sand dredging operations and the inadvisability of raising the brush and rock fill dam previously mentioned to a sufficient height to overcome this loss in head, it became necessary in 1916 to install a motor-driven low-lift centrifugal pump of 5,000,000 gallons daily capacity to furnish water to the emergency filters during periods of drouth. This plant was replaced the first of this year by a permanent low-lift pumping station located at the extreme end of No. 6 gallery. The station contains two motor-driven centrifugal pumps, each of 5,000,000 gallons daily capacity, which take their water from the river and discharge it into a series of ditches and pools extending along the land side of the gallery as far as the emergency filters. It has been demonstrated that this method of irrigation furnished water of equal quality to that filtered from the river and that it filters at the rate of about 1,000,000 gallons daily per acre flooded. At present only one pump is operated and then during only low-water stages of the river, although the average daily consumption has grown to over 8,000,000 gallons daily and a maximum rate of 17,000,000 gallons was reached last August for a short time.

In the normal operation of the galleries the pumping engines at the pumping station lower the water level of the suction well by their demand and this unstable condition of the ground water level thus created causes a draft on the gallery conduits which in turn is replenished by infiltration from the adjacent water-bearing area. The ground water then flows from either side towards the gallery; the greatest amount, however, coming from the river side. During periods of high pumpage the ground-water level immediately adjacent to the river has been drawn to a foot below the level of the water in the river. This heavy draft does not increase the yield from the river as much as might be expected, as it is limited by the permeability of the bed of the stream.

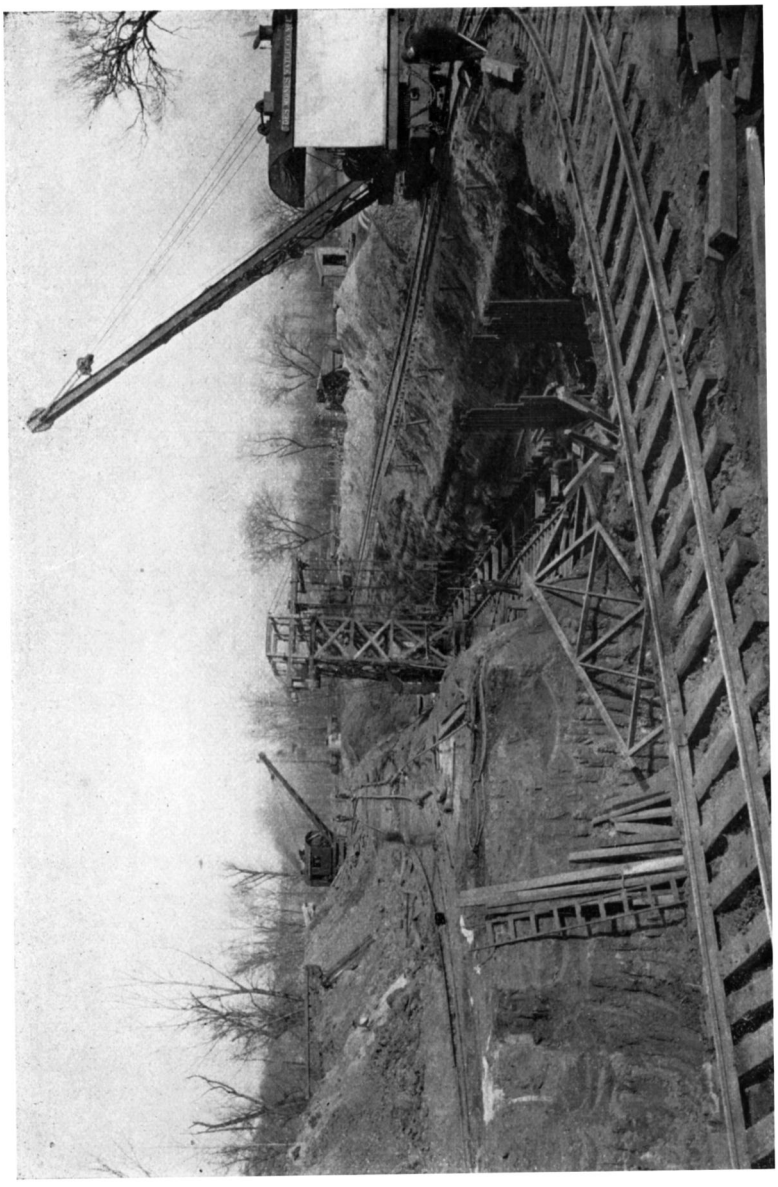

FIG. 4. VIEW OF WORK ON THE TRENCH FOR GALLERY NO. 6

In conclusion it is of interest to note the bacterial results of the operation of this natural filter plant. A chemist and two assistants are regularly employed to observe the character and quality of the water, making daily analyses of water from the river, suction well, and tap. During last year the average daily bacterial count of the river water, with samples incubated at 20°C. was 19,047 per cubic centimeter while that of the water in the suction well, as filtered through the sands, was 1061, showing a reduction of 94.5 per cent. The water is further treated with chlorine gas applied by an automatically operated machine which reduced the average daily count for last year to 47.5 or a total reduction of 97.5 per cent. It might be added that this average count at the tap is about double the normal actual count per day, the increase being due to a few high counts caused by abnormal fluctuations in the river.